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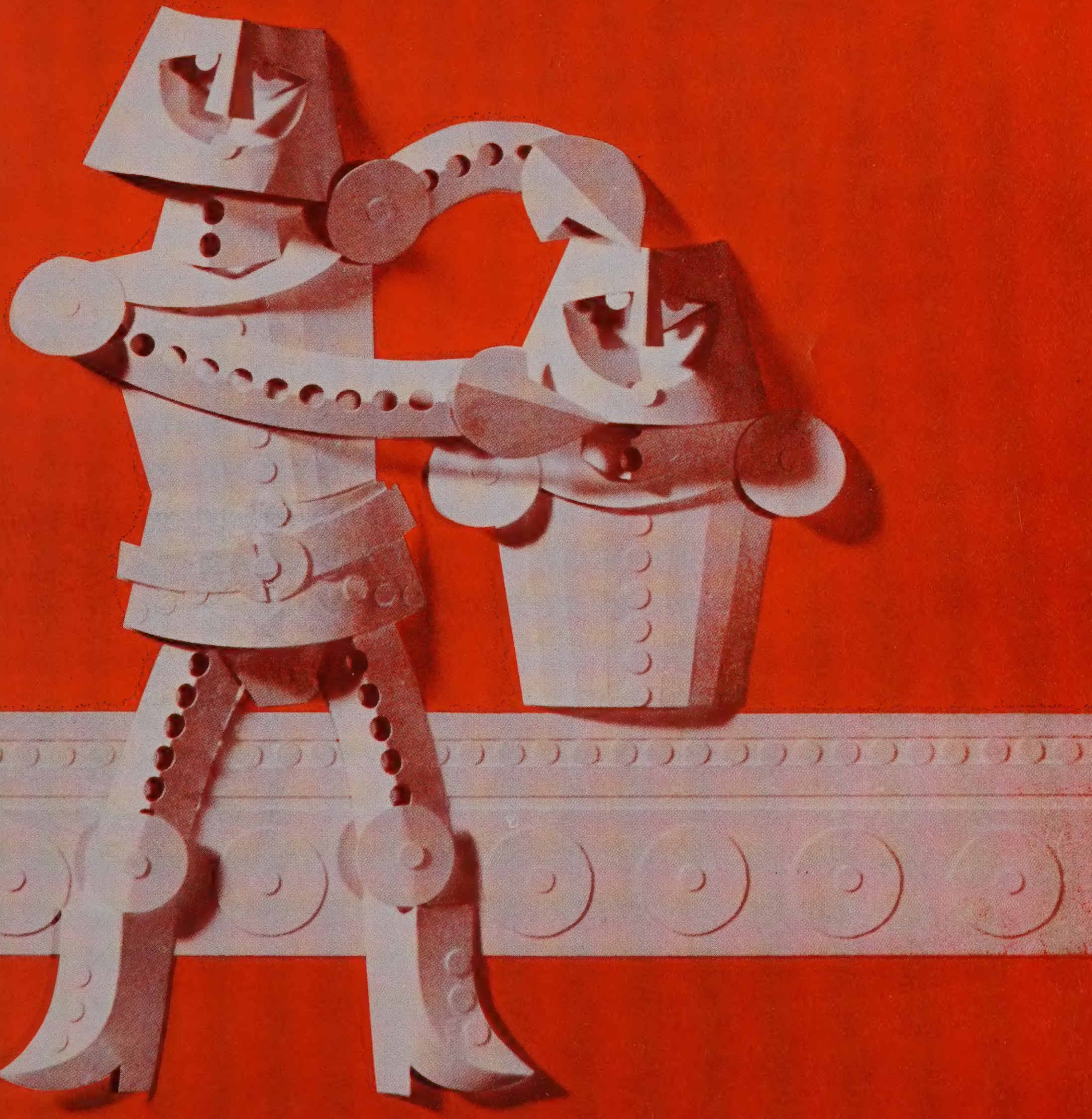

Robots- Now and in the Future

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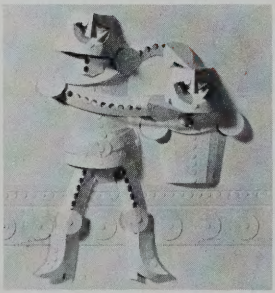

Cover: By the 1980's, the existence of highy automatic, self-reproducing robot factories may become a reality. In fact, there are already powerful economic forces pushing the introduction of robots to increase productivity and reduce costs. For a look at the status of robots today and the potential for tomorrow, see "Robots—Now and in the Future" on page 246.

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The National Bureau of Standards serves as a focal point in the Federal Government for assuring maximum application of the physical and engineering sciences to the advancement of technology in industry and commerce. For this purpose, the Bureau is organized as follows:

The Institute for Basic Standards
The Institute for Materials Research
The Institute for Applied Technology
The Institute for Computer Sciences and Technology
Center for Radiation Research
Center for Building Technology
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MANKIND AND THE TECHNOLOGICAL IMPERATIVE

Excerpted from a speech given by Dr. Richard W. Roberts, NBS Director, before the convention of American Home Appliance Manufacturers on October 18, 1974.

MAN is more than the naked ape. He is the inventor, the builder. He has taken his world and used it. He didn't call it technology in the early days, but technology it was. Making a simple spear was technology. Building a crude shelter was technology. Weaving a cloth was technology.

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Early technology was very different from today's. First, most of the energy came from muscle power — either man's or his beast of burden. Second, there were no organized, formalized attempts to develop technology. In most cases it was a product of need, of expediency, rather than the deliberate application of nature's laws. Furthermore, the population was such that technology's total impact on the world was limited. If the supply of flints ran short in one area, the whole village could move to a new source without too much disruption.

As time went on—as knowledge accumulated through trial and error—two interlocking phenomena occurred. First, world population started to rise. This rise was due in part to the switch from the occupation of hunting to that of agriculture. It was also due to the application of early measures of sanitation and medicine. Second, man began to use his knowledge in a more systematic way, to exploit and control more of his environment. An interesting loop was created: more people developed more knowledge which led to more use of natural resources. In turn this gave us the capacity to support more people. In effect, a self-accelerating situation was created. The development of science and its injection into this loop served to further accelerate the process.

Mankind is becoming the product of the technology he developed. Our life styles are shaped by technology; so are our social institutions. Development of the automobile allowed a mobility that has had dramatic effects on the landscape, the environment and the family. Existence of the auto has created the need for institutional controls for its use. Without autos there would be no Department of Motor vehicles, no licensing agencies, no parking meters. In some cases technology has also shaped individual man. Better nutrition in the last few decades has resulted in a dramatic increase in the average height of today's youth.

The partnership of man and technology is inescapable. The only question is that of degree. A New Guinea native may use a stone ax to chop down a tree; we use a chain saw. Both are examples of technology in action. The plain fact is that without technology, even on a primitive level, most of civilization would disappear. So if we are to continue in anything like our present life style, the outlook for technology is good.

Technology has always been a mixed blessing. The fire that warmed primitive man could also burn his hide. The factory of today can pollute while it produces. The negative aspects of technology have disillusioned some people. They fear the excessive impact that technology can have on the physical world and on society. They fight the exploitation of what little wilderness remains; they question the safety of nuclear technology. And I'm glad they do. For in a world dominated by technology, tunnel vision can be a common and dangerous affliction. We need to pause, to consider, to plan with care, and we need those who push us in that direction. But polls have shown that the majority of people still respect the professions of scientist and engineer, and still enjoy the products that result from their labors.

Technological problems, either real or fancied, have caused some people, especially in the under-30 age group, to, in their own phrase, "turn off." But have they? Only partially. A big thing with many dropouts is their super motorcycle, a product of advanced technology. Most dropouts really dig their stereo rig, a sophisticated piece of electronic technology. Those who formed communes have found farming hard work, and food stamps have bailed out many such groups. The food made available to them is the product of intensive agricultural technology. I'm not knocking those that drop out. It's reassuring that we have such freedom of choice. But I do say that no one can escape technology, no matter what his attitude towards it.

Even to us who haven't dropped out, it's clear that the world is far from perfect. But since technology is an integral, vital part of our lives, it's clear that we must use technology to help solve the problems we face. Notice I said help. Technology is just one of many tools, but an indispensable one.

Let's look at some of the problems, and see how technology can aid in their solution. Consider food. We in this country have been fed—often overfed—by the efforts of technically sophisticated farmers. Food exports have been a major factor in our balance of trade, and in helping to feed people around the world. But the harsh fact is that millions of people live on substandard diets. Famine reaps a deadly toll each year. You may ask what can be done. Certainly we can export more know how, more modern farming tools, more food produced by better technology. The food we export can be better matched to the needs and habits of the people who use it. The food can be better packaged, to ensure that a minimum amount is lost to spoilage and insects.

Another alternative to the food problem is that of population control. Zero population growth is close to a reality in this country, but in many foreign nations it is a goal many generations away. In fact, at the World Population Conference held in August, some nations indicated they had no plans to control population growth. Not only is population growing in many areas, but so are the people's expectations. They want a piece of the action, and who can blame them? Why should they cook over primitive charcoal stoves while we use self-cleaning ovens? Therefore, ways of meeting their demands—indeed those of our own people—have to be met.

That brings me to another problem area—materials. Earth has its limits. A generation ago its resources seemed infinite; today we view it as a very small planet. Yet our use of raw materials is staggering. Each year 18,000 kilograms (40,000 pounds) of the earth's precious resources are used for each American, including 4,100 kilograms (9,000 pounds) of gravel and sand, 540 kilograms (1,200 pounds) of iron, 3,510 kilograms (7,800 pounds) of oil and 2,250 kilograms (5,000 pounds) each of coal and natural gas. Even the most optimistic, or the most callous, must realize this pace cannot go on forever. Here again there are techniques that can keep us from going materials bankrupt. One is the use of substitute materials. Another is economy of design. Why should cars weigh 2,250 kilograms (5,000 pounds), when for most purposes 1,125 kilograms (2,500 pounds) will do?

A new outlook on design is needed, one that considers not only form and function, but materials use, repair, and longevity as well. Reliability can cut down on service calls and warranty claims, both of which can wipe out profit. Longevity depends not only on design but also on product testing, an area in which we need to make great progress. Nondestructive evaluation (NDE) techniques offer great promise in the rapid assessment of individual products. But the field of NDE needs major development before it becomes a routine tool in quality control.

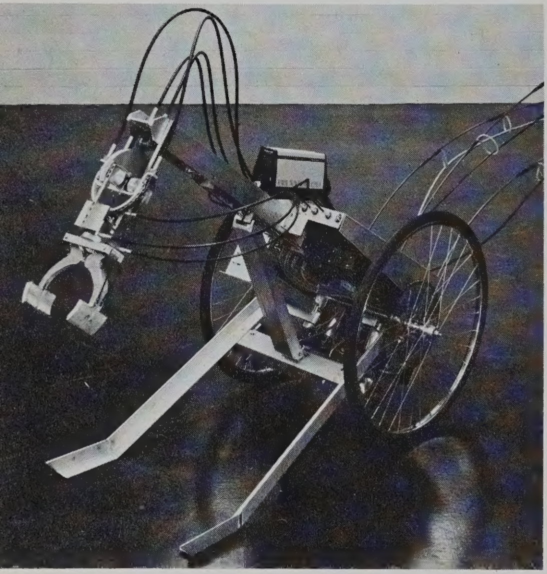
Let me summarize a bit. I believe technology is an inescapable part of man's culture. It always has been; it always will be. We cannot turn it off, we cannot send it away, we can only use it and control it to the best of our ability. I believe that an overwhelming majority of Americans support science and technology, and that most people in less advanced countries want their share of the technological pie.

The blessings of technology are often diminished by what doctors call adverse side effects. I believe that most of these side effects can be anticipated and their impact greatly reduced. And that brings me to my final point. Science and technology resemble a rather exclusive, clannish fraternity. A prerequisite for joining is training in a specific, often difficult, discipline. The members tend to speak mainly to one another. That cycle needs to be broken if we are to realize the full benefits of technology. The voice of science and technology needs to be heard in the corporate board room, in the city council chamber and at the highest levels of government. The message must be clear and in common language, so that non-specialists understand what is being said.

However, not all of the problems of technology imply a technological solution. Solutions to most of our problems call for inputs from many areas; they also call for an "early warning system," based in part on data from technologists.

The challenges that face us are enormous; our technological potential is equally great. The task of matching the two for the common good is our number one priority. My prescription, my prediction, is: more technology, not less; more technologic input to decision making at all levels; more attention to potential technology hazards; better use of material resources; more solutions of a social-technical nature; and continued questioning of technology. In other words, a challenging, exciting future that will involve all of us in the quest for a better tomorrow. ☐

Robots-Now and in the Future



Low-cost, mobile robot built by NBS for the U.S. Department of the Navy to prove the feasibility of using low-cost, readily available components in robot construction. NBS is now preparing specifications for the Navy to use in competitive procurement.

*by John M. Evans, Jr. and James S. Albus**

THE near future holds the promise of manufacturing industries based on integrated systems of robots and automatic machinery.

This is not science fiction; robots are already working in industries at hazardous or unpleasant tasks. Between 1,500 and 2,000 robots are in worldwide use today in such jobs as loading and unloading die casting machines, punch presses and forging machines; spray painting; and spot welding. These machines, even if somewhat limited in what they can do, are already reliable and cost effective in a working manufacturing environment.

By the 1980's robots will be available with sensors and computer control systems that will allow them to adapt to changing conditions in their environments, thus enabling them to carry out productive tasks such as loading and unloading of machine tools and assembling final products; completing oil wells at depths beyond which divers can operate; mining, tunneling and other dangerous and undesirable tasks. The technology needed to build such robots is already here or is being developed in laboratories around the world.

Current Robots

The simplest robots are "put and place" mechanisms with only a few degrees of freedom, suitable for part handling or assembly and simple machine loading and unloading. Such simple machines usually have pneumatic actuators and mechanical stops for position control. The sequence of operations of the robot is controlled by a pneumatic or electrical plugboard. Each row of the plugboard represents one direction of motion of one joint and each column represents one program step. Diodes or pneumatic lines are inserted in appropriate rows to determine which joints are activated, and in which direction, for each program step. When a joint is activated it is run wide open to the limit of the mechanical stop. These stops can be repositioned when a program is changed. Sequencing of program steps can be by fixed timing or external interlock with other machines.

A higher level of sophistication is obtained by adding a position control circuit to each joint. This requires feedback on the position of each joint, which is accomplished by potentiometers, encoders or resolvers.

The simplest way of programming such a system is the potentiometer board, which is conceptually like the plugboard controls with one row for each joint and one column for each program step. With this system, however, the position of a joint for a given step is determined by the value set on the potentiometer rather than a mechanical stop. Thus a given joint can be moved to any number of different locations in subsequent steps, which is not possible with the simpler robots.

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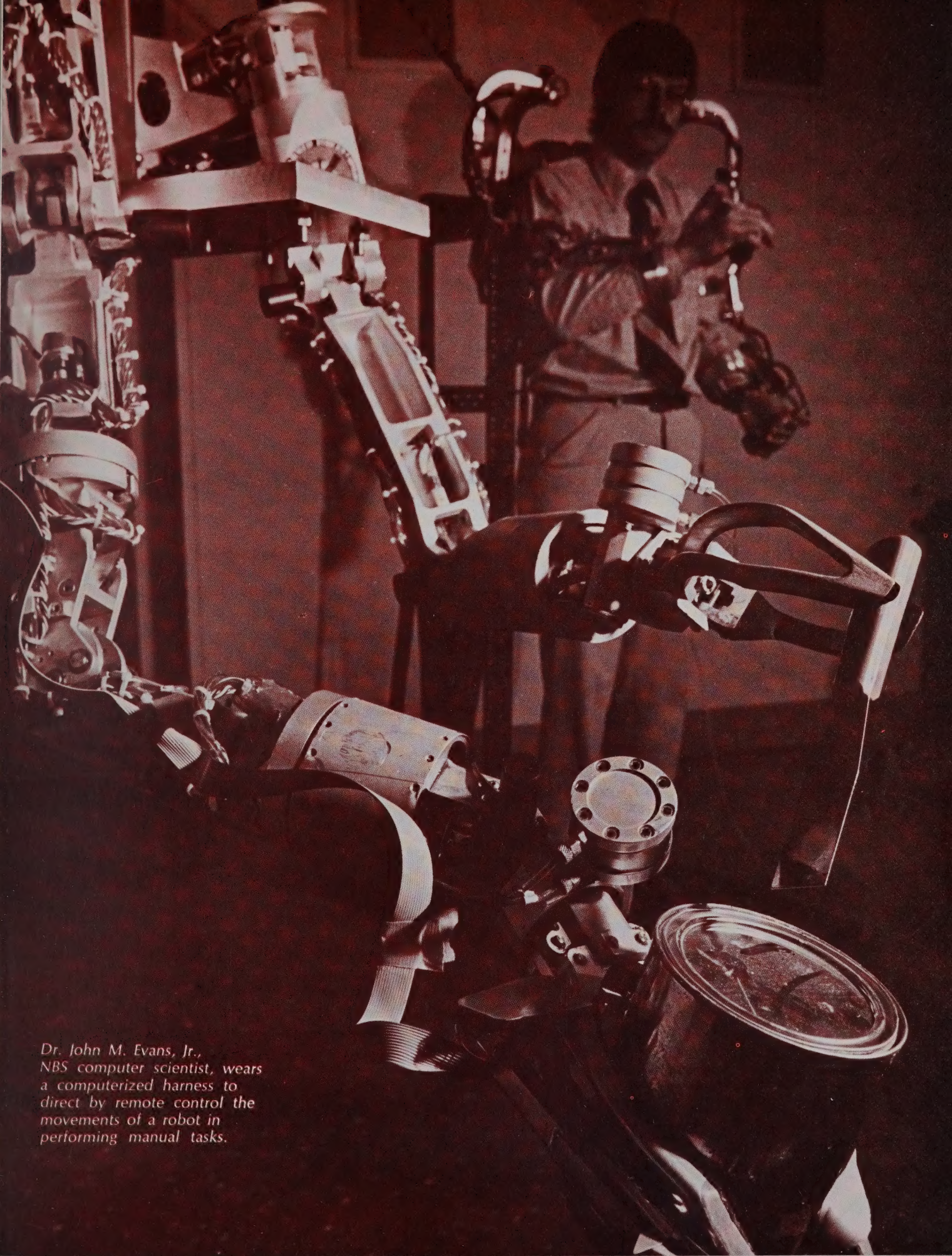
* Dr. Evans is acting manager of the Office of Developmental Automation and Control Technology at the National Bureau of Standards. Dr. Albus is a project manager within the same group.



Dr. John M. Evans, Jr., NBS computer scientist, wears a computerized harness to direct by remote control the movements of a robot in performing manual tasks.

Another type of robot, which has accounted for the majority of sales in the United States, uses digital servos and has a plated wire memory. Programming is accomplished through a hand controller that has a rate control button for each joint. Using the rate control switches, the robot is guided to the desired position and a "record" button is pushed, storing the position of each joint. In playing back the program, the control system carries out point-to-point servoing for all joints simultaneously for each step. Fixed timing, completion of the last step or external interlock may be used to determine the advance to the next step.

This robot may have several programs stored in its memory and will select one depending upon external commands or sensors. For example, it was used to do spot welding of two different models in an automobile assembly line.

Still more advanced robots use continuous trajectory programming. This is not actually a continuous trajectory but rather a trajectory sampled at closely spaced points. Location of the joints at equal increments of time are recorded on tape or in a computer memory as the robot is led through the desired motions. Point-to-point servoing is still taking place when the program is played back, but the points are close enough together that a smooth coordinated motion of all the joints is obtained.

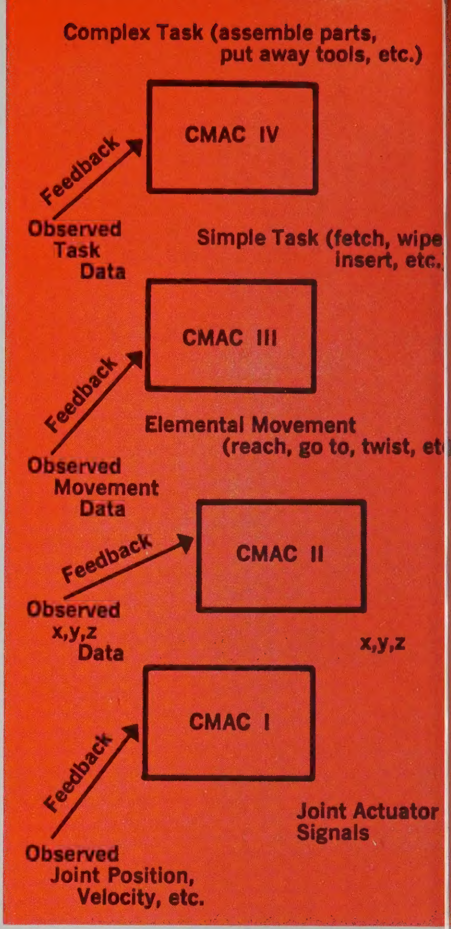
Projections for the Future

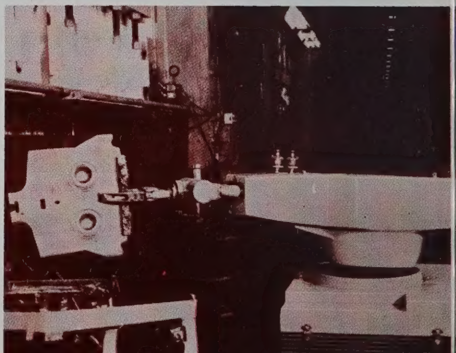
These are the robots and control systems of today. In the very near future, however, robots will be available with expanded capabilities through the addition of simple sensors and computer control systems. These additional capabilities will make robots easier to program and will allow the robots to adapt to changing conditions in a partially unconstrained environment.

The use of touch, force and proximity sensors is being explored at several laboratories, and significant experiments have been conducted to demonstrate the increased capability possible with the addition of these sensors. For example, the Artificial Intelligence Project at Stanford University achieved the assembly of a water pump using only touch sensors on a computer controlled manipulator. The Draper Lab at the Massachusetts Institute of Technology has shown how a manipulator with force sensing can follow surfaces or edges and can insert pins into holes with very tight tolerances.

A great deal of research has gone into general vision systems for robots and during the 1980's such complex sensors will be in use with manufacturing robots.

The general problem of automatic control of machines may be struc-





Top. *Example of a hierarchical control structure.* Center. *Automation is now being used in public service. For example, the city of Scottsdale, Ariz., is using experimental robot garbage collectors in their automated garbage collection system.* Bottom. *Industrial robots can perform many hazardous or routine jobs. Here a robot extracts a part from a clearing press.*

tured as a hierarchy of control functions, with each level of control calling up ordered sequences of operations at the next lower level (much like a computer program implementing a subroutine) using appropriate sensory feedback for each level. Man may enter the control hierarchy at any level for direct control or for programming the robot system for later playback. The basic concept is that man will program the robot in high-level task-oriented commands, and the computer will break these down into a series of elemental motor actuator signals.

NBS Research

The NBS Automation Technology Program has been investigating one particular approach to such higher level control structures for manipulators that promises to be both very powerful and very inexpensive. The Cerebellar Model Articulation Control (CMAC) system is a general purpose adaptive control system that can handle any kind of feedback variable such as misalignment of parts, variable mass loading, irregularities in materials and other constraints imposed by the external environment. All that is needed is appropriate sensors to tell the computer what is happening in the system being controlled.

Control functions may be represented in the form of equations. Control functions can also be stored as numbers in a table in a computer memory. CMAC uses a form of table look-up of control functions. Control commands and sensory feedback essentially define a memory address, with the contents of that location in memory being the value of drive voltages for a motor or a servo valve.

This technique of storing control functions numerically has generally been considered impractical because of the large amount of memory thought to be required. However, CMAC uses a form of addressing and data storage that allows control functions for real problems to be stored in a computer memory that is small enough to be economically feasible. CMAC may be implemented on very small computers, even microprocessors, and is useful in any case where control functions are difficult to define analytically such as when there is a great deal of sensory feedback to be processed.

CMAC is, of course, only one approach to implementing higher level control and has yet to be proven in practical applications. The use of table driven control systems, with interpolation capability, does appear to be a very powerful general concept, however, and should allow the development of robots that will be both sophisticated and inexpensive.

Service Applications

We have focused primarily on one aspect of automation in this article, the control and use of robots in manufacturing. The same basic technology is applicable to controlling all kinds of machines for service sector applications as well as for manufacturing. For example, there are now computers built into cash registers (point of sale terminals), cars can be plugged into computers for diagnosis of their problems and computers have even entered the entertainment field, controlling ping pong and other games played on a TV screen.

Airline autopilots, automated clinical analysis and automated garbage collection systems are further examples of applying automation in the service sector to increase productivity and to improve working conditions for man.

Institutional Problems

The development of the technology for advanced robots with sensors and computer control systems appears straightforward; there seems to be no major technical barriers to achieving highly automatic, self-reproducing robot factories in the 1980's. In fact, there are already powerful economic forces pushing the introduction of robots to increase productivity and reduce costs. Obviously, there will always be some people around to cope with emergency situations and breakdowns and with initial programming, but the number of people actually operating machine tools may be reduced significantly.

The real problems in achieving automatic factories will thus be economic, social and political. If the robots do the economically productive work, how do people receive any income? And, just as important, if robots are to create most of the material wealth in our society, who will own them and control the powerful economic and political forces they will represent?

These problems must be faced along with the technical problems if this country is to obtain the increased wealth and leisure time that appear possible when robots are widely applied in manufacturing and service tasks in the next few decades. ☐

A Modern Fish Story

NBS in Joint Effort to Solve Problem of Salmon Fisheries Productivity

FEW projects demonstrate the diversity of activities and talents found at the National Bureau of Standards as well as one which has been recently undertaken for the State of Washington and supported by the Commerce Department's National Marine Fisheries Service. Salmon, a lottery, 14 Indian tribes, mathematical models, computers and a court battle are some of the key elements in this complex effort.

The first part of the project, recently completed, was the development of a large-scale mathematical model to assist in more efficient management of salmon hatcheries in Washington. The model has been successfully implemented, contributing to improved production in a number of the State owned and operated hatcheries.

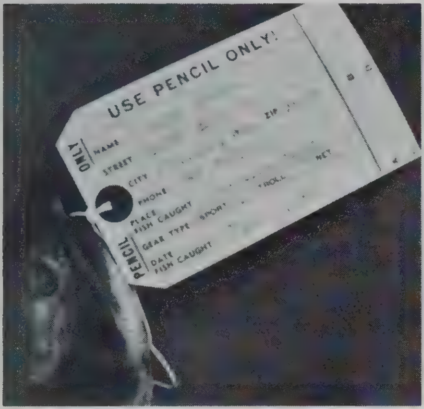
A second part of the project, just getting underway, involves developing a mathematical model of activities in the State's salmon fisheries. Fisheries refer to areas where the fish are caught as well as to fishermen in the areas. This activity was spurred by a recent court decision ordering restoration of the salmon fishing rights guaranteed to local Indian tribes by 19th century treaties. The model will be used to estimate what effects various changes in regulatory policies designed to meet the court order will have on the sport and commercial salmon industry which contributes $150 million annually to Washington's economy.

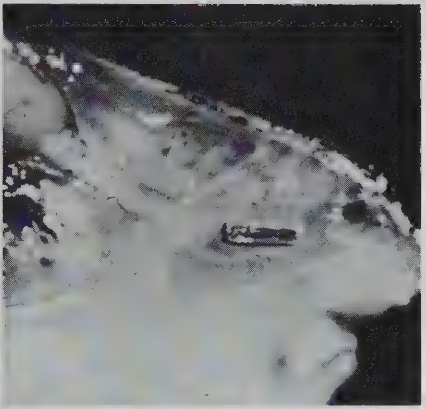
Representing the NBS in the project is Dr. Frederick C. Johnson of the Applied Mathematics Division. Johnson developed the current version of the hatchery model at the NBS Gaithersburg labs in Maryland and for the next 2 years will be in Seattle with Dr. Peter Bergman and Sam Wright, State fishery biologists of the State of Washington Department of Fisheries. At the same time Johnson is developing the new fishery model, he and hatchery biologists from the State will be evaluating the hatchery model and its implementation.

Life Cycle

Understanding the life cycle of the Pacific Coast salmon is crucial to the development of these models, according to Johnson. Pacific salmon live most of their lives in the oceans but as adults they return to fresh water streams and rivers—more than 1,000 salmon-bearing streams in Washington—where they spawn and die. The construction of power dams, large scale logging operations and urban growth in general in the State have severely reduced the number of natural spawning grounds. Because of salmon's economic importance, the State owns or operates 26 hatcheries to sustain artificially and rehabilitate natural runs of Pacific salmon, in particular the Coho and Chinook species.

Johnson has been working on various aspects of hatchery operations since early 1971. NBS became involved in salmon hatchery modeling in the summer of 1973 when Washington State officials, lead by Bergman, requested assistance in increasing the efficiency of the State's hatcheries. It was the State's idea to develop a mathematical computer model which would simulate the en-





tire life cycle of the Coho and Chinook salmon while taking into account the factors of hatchery operation. So the mathematician and computer expert was brought together with the biologist to solve the problem.

Microtags and Salmon

Operation of a mathematical model requires data, however, and basic information was needed on how many of the salmon reared in hatcheries actually do return to the streams and how many are caught by the commercial and sport fishermen. Data of this kind were made available as a result of a unique and novel identification method developed around 1960.

At that time, Bergman and Dr. Keith Jefferts (now a radio-astronomer at Bell Telephone Labs in New Jersey), headed a team of biologists who developed a "microtag" which could be inserted by machine into the head of young salmon while still in the hatchery. At the same time the microtag is inserted, the salmon's adipose fin is clipped. This makes possible the visual identification of the tagged adult fish when it is caught by fishermen.

The microtag, barely visible to the human eye, is a millimeter long and has a diameter of ¼ millimeter. Information is etched on the microtag using a binary code.

When a sport fisherman finds an adult salmon with a clipped adipose fin, he is encouraged to cut off the fish head and leave it at the dock where it is collected by the State Department of Fisheries for removal and identification of the coded information on the microtag. A State operated lottery with cash prizes is an extra inducement for the fishermen to turn in their salmon heads. The State gets data from commercial salmon fisheries by sampling a portion of the catch.

Hatchery Model

The data collected from the microtags made it possible for Johnson to develop the hatchery model. The model consists of a set of mathematical equations, performance tables and logic which, when applied, reveal the economic impact of hatchery operations on fisheries. A linear programming analysis is used to compute optimal management policies for the hatchery. The analysis relates the water requirements for each species in the hatchery (which depends on weight, water temperature and population size) to the water available to the hatchery on a semi-monthly basis. The model also simulates all major processes of hatchery operation including growth, pond management, natural mortality, pollutant production and cost of operation.

The model developed by Johnson predicts the benefits obtained from various management policies and thereby suggests operating methods which will result in the greatest economic contribution to the fisheries by the hatchery for the time and money invested. Originally validated on the NBS computer, the model was subsequently converted for use on the computers at the University of Washington in Seattle.

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Stair Safety: Research/Code Requirements

Under sponsorship of CPSC, the National Bureau of Standards is conducting extensive research into safety aspects of stairs, ramps and landings. The goal of this research is to produce information necessary for developing performance standards and design criteria that can be used by builders and architects to reduce the number of stairway accidents.

John Archea, NBS research psychologist, points out that most building codes deal with stairways primarily in their function as fire exits. For example, the carrying capacity (stair width), which is often cited in commercial building codes, must bear some relation to the occupancy load or to the total number of persons who will be using the building. "This is obviously an important consideration if the stairway is to be used by all building occupants at once, as during a fire evacuation," said Archea. "But, except for handrail requirements, design features that relate particularly to safety of stairways in normal use are often ignored in codes."

Even in cases of building codes that do specify such stair design features as the riser height or depth of tread, the empirical basis for their requirements may be open to question. For example, the requirements for design of steps cited in several model building codes, and in codes for some of the Nation's largest cites, were devised in the late 17th century by Francois Blondel, a French architect. According to John A. Templer in his doctoral thesis prepared at Columbia University, Blondel noted that "the length of a comfortable pace of a man who walks on the level is . . . 24 inches. And the height of one climbing a vertical step is only 12 inches." Blondel concluded that for every inch of height for the riser, one must subtract 2 inches from the pace, or expressed mathematically: $2 \times \text{Riser} + \text{Tread} = 24$ inches.

In light of changes known to have occurred in average body sizes in the ensuing 300 years, one may reasonably question the adequacy of Blondel's formula for modern building codes. Moreover, the "inch referred to in Blondel's formula was probably the French (pre-Revolutionary) Royal inch, which is equivalent to 1.0568 inches in today's measure. This fact may tend to cast further doubt on continued unquestioned use of the Blondel formula.

Environmental and Behavioral Factors

NBS researchers are working under the assumption that all stairway accidents are caused by a combination of environmental factors and human behavioral factors.

Environmental factors include such considerations as adequacy of lighting and the physical organization and dimensions of the stair assembly; the quality of elements used in the structure, with their bearing on durability of treads, railings and other hardware components; or particular items identified with the person, such as articles of clothing or objects being carried that may cause entanglement.

Behavioral factors leading to accidents may involve: voluntary acts such as running on stairs or horseplay; advanced age or medical conditions causing reduced physical abilities; or social interactions, including distraction by others and rates of pedestrian flow.

Accident Behavior Model

A conceptual model of stairway accident behavior developed by Dr. Carl Johnson of NBS' Architectural Research Section, is being used by NBS researchers to study systematically the interactions between the stairway user and features of the stairway environment that can lead to accidents. "Once the 'linkages' between environmental factors and behavior are more completely understood, stairway design criteria can be developed on the most rational and effective basis," Johnson noted.

"Anticipation or expectation is a concept that is crucial to the stairway accident model. Accidents occur because the reality of the stairway, or the reality of one's performance on the stairway proves to be other than what was expected, he said. Thus, accidents occur when people unexpectedly encounter physical obstructions (such as toys left on the stairs); or when they fail to en-

h Your Step!

STAIRWAYS and steps are common building features. They are essential structural components of nearly every home, apartment and place of business.

But they are so much a part of our environment that we take them for granted—and herein lies a danger: we use stairs so often, and without incident that we may fail to accord them the same respect as we do other products, such as power mowers or automobiles, that seemingly present more obvious hazards.

Yet, according to the Consumer Product Safety Commission (CPSC), among all consumer products, stairs rank second only to bicycles in frequency of association with accidents. For women over 16 years of age, stairways lead all other consumer products in their association with accidents. In a recent year it was estimated that 356,000 Americans were injured in accidents related to stairs, ramps and landings. Many such accidents are severe, resulting in broken bones, head and internal injuries and even death.

counter surfaces or obstructions that are anticipated (such as a handrail); or when surfaces or obstructions prove to be more or less resistant than anticipated; or when one misjudges his own physical capabilities.

Essentially, the accident behavior model examines in detail the sequence of events that occurs in stairway use: that is, perception by the user of important stairway features,

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STEP *continued*

such as riser height and slipperiness; choice of how to negotiate the stairway (whether to run or walk, to use the handrail or not); and actual negotiation of the stair.

Study of the model has suggested several measures that may be taken to avoid the kinds of "linkages" between environment and human behavior that can lead to accidents. For example, someone going down a flight of stairs leading to a subway station is usually very intent upon catching the next subway train. If, mid-way down the flight he hears or sees the train pull into the station, the temptation is great to run down the stairs. The hazard is compounded by the fact that attention is likely to be focused on the train, making the stair-user less likely to notice any irregularities or obstructions on the stairway. An obvious design solution to such a problem might be to enclose the stairway in such a way that the sight and sound of trains on the platform would be effectively blocked until one reached the lowest landing.

Similarly, consideration might be given in the design of stairs to avoiding exposure by the stair user to the possibility of extremely novel stimuli, such as loud noises or sudden and distracting changes in vista. Such stimuli would be likely to cause a monetary "orienting response" which might disrupt ongoing movement, and could contribute to a fall.

Use of Films/Video Tapes

In an effort to test specific implications of the accident behavior model, stair users on stairways were filmed and video taped in a number of public places including several schools, a shopping center, an airport lobby, and at several dining and recreation facilities frequented by large numbers of elderly persons. Stairways selected for filming were considered "typical" for their purpose and environment, and did not display obvious design hazards. Analysis of the films and tapes yielded considerable insight into the way people actually negotiate stairs. The sequence of events resulting in several trips and falls were also taken on film and provided valuable information on how accidents occur. In addition, examination of the video tapes revealed other unanticipated patterns of behavior that may influence the occurrence of accidents. For example, it was noted that stairway movement tends to be synchronous among people moving on a stairway together and who are engaged in some social activity, as in conversation.

Design Criteria Priorities

Results of the study to date indicate that stairway design criteria and code provisions relating to stairway safety should address at least eight priority concerns. These include:

- Conspicuousness—Conditions in the architectural and social environment that tend to draw attention to potential hazards or to divert attention away from them.
- Configuration—Physical dimensions and other attributes of the stairway component.
- Special populations—Difficulties experienced by the elderly, infirm or the very young.
- Traction—Resistance provided between a walking surface and the shoe or human foot.
- Retrofitting—Alteration or re-equipment of stairs and ramps already in place to bring them into compliance with new design criteria.
- Durability—Ability of materials to withstand wear and weathering.
- Impact—Capacity of a surface or protrusion to produce injury. For example, impact-related criteria may define the sharpness of nosings on stairway treads in order to reduce the risk of injury in the event of a fall.
- Entrapment—Positioning of a stair or ramp in a manner that lures the user into negotiating them unnecessarily or under cumbersome conditions. Examples of entrapment include stairs with light switches placed only at the bottom so that a householder must descend the stairs to turn off the light and then ascend in the dark; or situations in which a door opens directly onto a stairway.

In some ways, the subtlety of the danger presented by most stairways increases the risk they pose. By identifying stairway hazards, by increasing the level of awareness of this problem on the part of builders and architects, and by providing the basis for sound performance standards and design criteria, NBS research should contribute to significant improvement in public safety. □

HIGHLIGHTS

Urethane Combustion Products Toxic

Recent experiments conducted at the University of Utah, under the sponsorship of National Science Foundation in cooperation with NBS, show that combustion products from certain fire-retarded polyurethanes have harmful effects on the central nervous system. Laboratory rats exposed to smoke from these materials exhibited varying degrees of seizures and generally died within 10 minutes. The toxic agent in the smoke has been identified as a complex organic phosphate which is produced in small quantities during the combustion process.

NBS has informed the Consumer Product Safety Commission of these test results and is sponsoring studies both at Utah and the University of Pittsburgh to determine whether toxic products can arise from the combustion of other plastics.

Appliance Labeling

The second energy labeling specification for household appliances is nearing completion under the Bureau's Energy Conservation Labeling Program. The specification will call for the labeling of refrigerators, refrigerator-freezers and freezers with information on the monthly energy consumption and energy cost of individual models. Cost information will be based on varying electric rates. Consumers will be able to compare a model's energy consumption and the cost of the energy with other similar models on the market.

New Reference Fuels

Two new standard reference fuels, n-Heptane and Isooctane—SRM's 1815 and 1816 respectively, are now available from the Bureau. Both reference fuels are certified for density, refractive index, lead content and freezing and boiling points. N-heptane and isooctane are part of the system used to establish the octane-rating of motor and aviation fuels.

For additional information, write the Office of Standard Reference Materials, B311 Chemistry Building, NBS, Washington, D.C. 20234.

Air, Water Short Course

A short course on "Instrumental Methods for Air and Water Measurements and Monitoring" will be presented by NBS, the IEEE Nuclear and Plasma Sciences Society, the Atomic Energy Commission and the Environmental Protection Agency on December 14, 1974, on the NBS Gaithersburg, Md., campus. The program is structured to provide the concerned scientist and engineer with an up-to-date view of current techniques as well as those methods expected to be employed in the future.

For information, write to Ronald B. Johnson, B348 Materials Building, NBS, Washington, D.C. 20234.

Massachusetts Receives Standards

The State of Massachusetts recently received a 96-piece set of weights, measures and weighing instruments under the NBS program to provide new weights and measures standards to the 50 States. At a ceremony held in Boston, Dr. Betsy Ancker-Johnson, Assistant Secretary for Science and Technology in the Department of Commerce, presented the set to Donald Dwight, Lieutenant Governor of Massachusetts.

The new set of weights and measures is composed of standards of mass (weight), length and volume and the necessary laboratory instruments, including high-precision balances, to meet State weights and measures requirements.

Call for Papers

The National Conference of States on Building Codes and Standards has issued a call for papers in connection with a workshop being held with its eighth annual convention April 27 through May 1, 1975, at Santa Fe, New Mexico.

Interested parties are requested to submit papers on "Innovations in Building Regulatory Agency Management and Procedures" to NBS, which serves as the secretariat for the convention. A one-page typed abstract of each paper should be submitted on or before January 31, 1975, to Patrick W. Cooke, Office of Building Standards and Codes Services, NBS, Washington, D.C. 20234.

Coal Mine Safety

NBS, in an effort to speed mining operations, is studying the feasibility of using a microwave device, instead of drilled samples, to test the thickness of the coal layer, which for safety reasons must remain on the ceiling of tunnels dug through shale rock. The instrument currently under test is a dielectric-reflectometer. It consists of two small microwave horns side-by-side, which are pointed at the tunnel ceiling. A swept-frequency microwave signal, transmitted from one horn, is reflected at the ceiling and also from the coal-shale interface beyond. Analysis of the reflected signals may permit an immediate, continuous reading of depth for the coal layer. □

Procurement, Regulatory and R&D Systems Used to Spur Technological Innovation

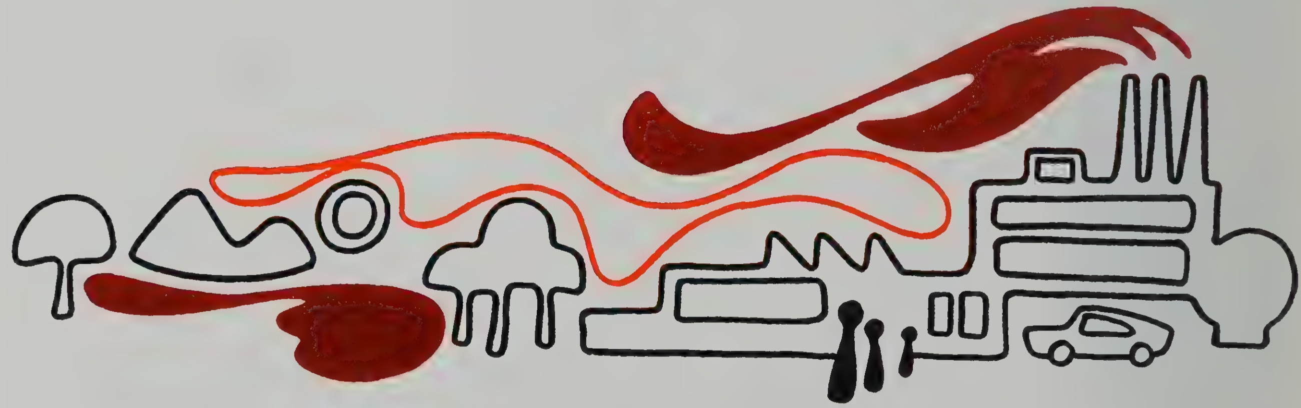
THE National Bureau of Standard's Experimental Technology Incentives Program (ETIP) launched more than a year ago (Technical News Bulletin, July, 1973) is moving into high gear under the capable leadership of Dr. Jordan D. Lewis. More than 70 projects relating to Federal policy on technology and its impact on the private sector have been initiated.

Among ETIP's accomplishments in FY 1974.

- More than one dozen Federal agencies made policy-level commitments to ETIP experiments, including commitments of $200 million in other agency funds.
- The General Services Administration created an Office of Procurement Policy Experiments in the Office of the Commissioner, Federal Supply Service (FSS), to coordinate ETIP experiments and integrate knowledge gained into FSS policies and practices.
- The Council of State Governments agreed to establish a nationwide state procurement specification system under ETIP auspices.
- ETIP initiated the use of life-cycle-costing in the Federal purchase of civilian goods. This means not necessarily buying from the lowest bidder but from the manufacturer whose product will be least costly to own and operate during its lifetime.

ETIP was conceived in the President's Science and Technology Message of March 16, 1972, which called for "determining ways of stimulating non-Federal investment in research and development and of improving the applications of research and development results."

ETIP is designed to use the policy apparatus of the Federal Government as a lever to stimulate research and development—and its application—by private industry. ETIP, with a modest $7 million annual budget, has the potential for influencing policy across a broad spectrum of Government and private organizations. These policy changes, in turn, could mean the spending of hundreds of millions of dollars in entirely new ways . . . ways that are beneficial for this coun-



try's economic and social growth.

Dr. Lewis sees ETIP as a catalytic agent that will disappear once it has produced change. ETIP is not expected to last more than 4 or 5 years as a Government entity. But in its wake it hopes to leave permanent policy changes in major Federal agencies. "We hope the other Federal agencies go right along with us and, when ETIP fades out, they will pick up the ball," Dr. Lewis says.

To effectively promote change, ETIP is divided into three program areas—procurement, regulation and research and development. All are aimed at influencing decision-making in other Federal agencies.

In the procurement area, under the direction of Theodore J. Fody, ETIP is using the purchasing clout of the General Services and Veterans Administrations to produce desirable technological changes in goods produced in the private sector.

As example, GSA has written energy-conservation requirements into specifications for 15,000 room air conditioners it is purchasing on bid. Hopefully by meeting the Federal Government's requirements, manufacturers will also extend this energy-saving factor to their lines of air conditioners for the public consumer market.

In Philip J. Harter's regulatory program, ETIP is working with the Environmental Protection Agency (EPA) to promote research and development of safe and effective pesticides by private industry. As the result of the Federal Environmental Pest Control Act of 1972, all pesticides will have to be registered with EPA by 1976 and shown not to be harmful to health and not to be cumulative in the environment. This may discourage private industry from developing new pesticides because of the cost of getting them approved, which Harter estimates is between $2 and $3 million for each new product. So, ETIP is working with EPA to devise some policy guidelines which would encourage continued research while assuring private industry a return on investment dollars.

"We're trying to look at specific examples of regulatory inhibitions. How can we accomplish regulatory objectives but in a mode that doesn't prohibit innovation?" Harter asks rhetorically.

Among the projects in the research and development program ETIP has awarded a $296,612 contract to Charles River Associates, Inc., a Cambridge, Mass., consulting firm, to develop an understanding of what Federal policies are needed—under what circumstances—to deal with major socio-economic disruptions (e.g., cartel-caused mineral shortages) where technological change is an attractive remedy. Dr. Harold J. Barnett, ETIP's chief economist who is managing this contract, says the Charles River Associates' analysis and report will be circulated widely in Government circles and the consultants will brief key Government officials on the results. The President's Council of Economic Advisers and the Treasury Department are cooperating Government agencies in this project.

Other ETIP projects in all three program areas cover a wide range of subjects including: refrigerated rail transportation, efficiency of electrical energy use in refrigerators, water heaters and ranges, building design alternatives, health care productivity and diffusion of university research output. In all of the projects is the common thread of using Government policy as a lever to promote technological innovation by the private sector.

ETIP is now starting to look at projects across all three program categories. "How does one orchestrate regulatory, procurement and research-and-development systems to improve the health-care system in this country, tackle material shortages and solve market fragmentation?" Dr. Lewis asks.

He cites a recent ETIP award of $474,821 to Clemson University to develop flame resistant cotton/polyester fabrics as an example of ETIP's new way of doing things. Under conventional thinking, he notes: "The Government picks a specific problem and goes to the place it thinks it can get the best research on the problem. Consequently the Government often gets good research results but they are not necessarily used by anybody."

With the Clemson award "we didn't just want to do research and development, we wanted to buy technological change—we wanted a high degree of assurance that the research and development will get used," Dr. Lewis says.

Clemson, acting for a consortium of universities, research laboratories and textile firms, submitted a plan with assurance that the results would be commercialized.

"We are far more interested in good research that gets used instead of great research that doesn't," Dr. Lewis emphasizes. ☐

Office of Energy Conservation Established

DR. Richard W. Roberts, director of the National Bureau of Standards, recently announced the establishment of a new Office of Energy Conservation (OEC) at NBS to advance the use of energy efficient technology in buildings, communities and industry.

"A strong national commitment to energy conservation is absolutely essential if we are to achieve the goals of Project Independence and continue to prosper as a nation," Roberts said in making the announcement. "OEC will provide NBS and the Commerce Department with a more coordinated and interdisciplinary approach in helping to reach those goals."

According to Roberts, OEC is responsible for developing and overseeing the Bureau's energy conservation programs and research, which is funded this fiscal year at $3.5 million. OEC also coordinates with other Federal agencies having energy conservation interests, including the Federal Energy Administration (which is funding a large portion of the OEC programs this year) and the Commerce Department's Office of Energy Programs.

Roberts named Dr. Jack E. Snell to head OEC, which is located in the Bureau's Center for Building Technology (CBT). Snell has been with NBS since 1971, most recently as assistant chief of CBT's Building Environment Division.

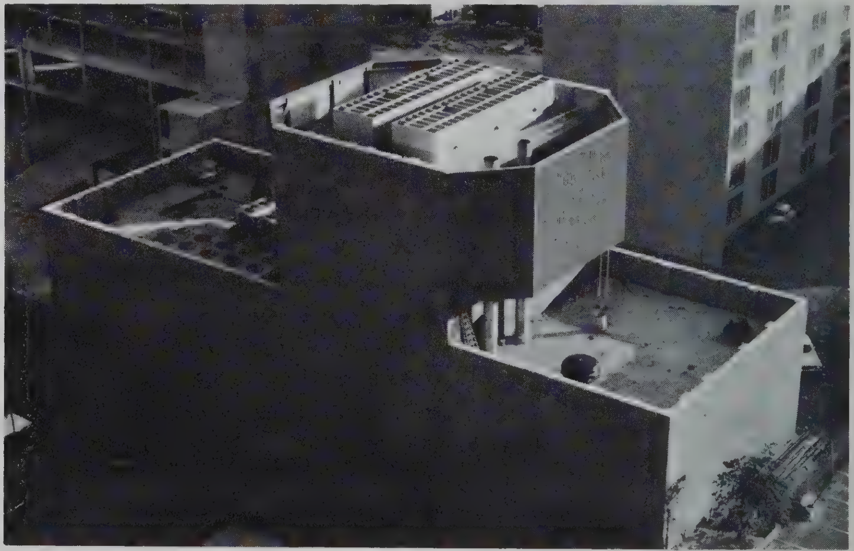
Projects are already underway in each of the three areas for which OEC has responsibilities—buildings, communities and industry. In the buildings program, for instance, OEC is carrying out research on retrofitting of existing housing, designing guidelines for new, energy efficient buildings, studying heating, ventilation and air conditioning systems in commercial buildings and improving measurement technology for each of these areas.

The major project in the communities program is the evaluation of a total energy plant in Jersey City. This evaluation is being performed under contract to the Department of Housing and Urban Development. The plant, when fully operational, will produce on-site enough electricity, heat, hot water and air conditioning for 486 apartments, a school and a commercial area. The Jersey City project is an example of a Modular Integrated Utility System (MIUS)—a total energy system with additional facilities for recycling waste products and water treatment. OEC's communities program also will evaluate for HUD another MIUS project which is scheduled for construction this year.

Industry projects in OEC include the development and implementation of "The Energy Conservation Program Guide for Industry and Commerce (EPIC)," a new handbook which has been developed to help organizations establish energy conservation programs or improve existing programs. Other projects include development of a guidebook to help engineers improve waste heat recovery in industrial furnaces, development of improved methods for measuring performance of industrial furnaces and development and demonstration of waste heat management systems.

Most of the research for OEC's projects will be carried out in the technical divisions of CBT and other NBS units. The remainder of the work will be contracted out. ☐

Aerial view of the total energy plant presently under construction in Jersey City.



4,000 Residences Surveyed for Lead Paint Problems

THE National Bureau of Standards has begun an experimental survey of 4,000 dwelling units in Pittsburgh, Pennsylvania, to determine the nature and extent of the lead-based paint poisoning problem there.

The work is being carried out for the Department of Housing and Urban Development in its implementation of the 1971 Lead Based Paint Poisoning Prevention Act. NBS has signed a $103,000 contract with the Allegheny County (Pennsylvania) Health Department to perform the survey.

It is the first time that a wide cross section of dwelling units and children in an urban environment will be examined for lead-paint hazards. The published results, expected in about a year, should become a valuable guide for other communities in estimating the size and severity of the problem.

Lead paint poisoning is a serious health problem in the United States. It is believed that 12,000 to 16,000 children become blinded, mentally retarded or otherwise impaired each year due to the ingestion of bits and chips of lead-based paint. More than 500,000 children have abnormally high levels of lead in their bodies and may suffer impairment of varying degrees.

The Allegheny County Health Department will examine physically the dwelling units in Pittsburgh and use instruments to measure the lead content of painted surfaces. They will also test children who are 6 years of age or younger in these residences for elevated blood levels.

The Allegheny County Health Department is sending out eight two-person teams to inspect the dwellings. While one team member operates a portable x-ray fluorescence instrument to measure lead levels in paint, the second team member will record the data and talk with the occupants. The raw data collected by county inspectors will be analyzed by NBS researchers who will produce a handbook for distribution to government agencies and other interested organizations.

"The ultimate objective is to develop a work manual that can be used by any city for surveying the extent of the lead paint hazard," explains Harvey W. Berger, NBS' lead paint program manager. The manual will contain survey techniques, statistical methodologies and computer programs and software for analysis.

Residences in Pittsburgh are being selected randomly according to age of housing, building size and occupancy by owner or renter.

After the selection has been made, the county health department will send letters to the occupants of the dwellings, explaining the intent of the program, the seriousness of the lead paint problem and requesting that the occupants allow the survey team to be admitted. The letter will be followed by the site visit.

NBS is assisting the Allegheny County Health Department by supplying—for the first time—a known, reliable standard for lead in blood. Using this standard, the capability of local clinical laboratories and the data on lead levels in blood can be evaluated. ☐

Low-Cost Housing Performance Examined

THE performance of low-cost housing in the violent windstorms that periodically invade many countries is closely examined in the latest Building Science Series publication of the National Bureau of Standards.

Appearing as BSS-56 in the series, the book embodies proceedings of a November 1973 workshop at Manila, the Philippines, part of a 3-year project sponsored by the United States Agency for International Development (AID).

Workshop participants and attendees, numbering about 140, came from Bangladesh, Jamaica, the United Kingdom, the Philippines and the United States. According to Alfredo L. Juinio, dean of the College of Engineering, University of the Philippines, the gathering represented probably "the first serious cooperative effort to seek local design criteria, particularly for low-rise, low-cost buildings."

Delegates to the first workshop recommended a variety of steps toward improvement of building practices and the upgrading of design criteria for low-cost buildings. Included were recommendations dealing with manuals of accepted practices; structural, roofing and cladding loads; maintenance considerations; wind tunnel model studies of buildings with unusual shapes; geographic distribution of wind recording stations; land use planning; post-disaster surveys; architectural and engineering licensing and education; and proposed establishment of wind research centers.

The workshop proceedings, "Development of Improved Design Criteria for Low-Rise Buildings in Developing Countries to Better Resist the

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HOUSING *continued*

Effects of Extreme Winds," may be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, or at U.S. Government bookstores in principal cities. Ask for SD Catalog No. C13.29/2:56.

A second conference in the Philippines has been targeted for April 1975, with arrangements now being completed by two officials of the NBS Center for Building Technology. They are Noel J. Raufaste, Jr., Federal building program coordinator, and Dr. Richard D. Marshall, structural research engineer and the project's principal investigator.

Sometime in the fall of 1975 there will be a third conference, to be held in Jamaica. A wrap-up Philippine conference is slated for the spring of 1976, marking the completion of the AID/NBS project.

Principal project funding of more than a half-million dollars from AID is being augmented by additional monetary support and donations of three parcels of land for the experimental test sites, test buildings, equipment, facilities and personnel provided by public and private agencies in the participating countries. □

Officer-in-charge (left) at Daet Station, the Philippines, receives instructions on assembly of an NBS pressure transducer from member of the government weather bureau.

NBS Report Spells Out Privacy Proposals

COMPREHENSIVE suggestions for safeguarding the privacy of individuals in computer-based recordkeeping systems are contained in a report just published by the National Bureau of Standards.

The proposals were made by legislators, managers, industrialists and technologists who took part in a conference on Privacy and Security in Computer Systems held earlier this year at NBS.

In releasing this report, Dr. Ruth M. Davis, Director of the NBS Institute for Computer Sciences and Technology said, "By disseminating the views of the conference speakers, we are continuing our efforts to stimulate actions on the part of responsible groups which can help resolve the difficult problems of data confidentiality and computer security."

The report includes recommendations to:

- Enact cohesive privacy legislation at the National, State and local levels of government.
- Provide legislative policies, standards and security requirements that will stimulate research and development of technological safeguards in the private sector.
- Develop and apply an effective balance of managerial, administrative and technological measures in safeguarding data confidentiality.
- Determine costs of data confidentiality as a basis for decision and allocation among those who must bear the expense.
- Enlarge the educational activities needed to improve understanding of the privacy, data confidentiality and computer security issues.

The conference on which the report is based was the second of two that were sponsored by NBS to highlight the problems that governmental managers face in protecting confidential data and the actions needed to provide effective safeguards against the misuse of such data.

The two conferences were attended by 886 persons representing the Congress, State legislatures, local government, the computer industry, trade associations, professional societies, universities and public interest groups.

The report issued by NBS is titled *Approaches to Privacy and Security in Computer Systems* (NBS Special Publication 404). It is for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, for $1.20. Order by SD Catalog No. C13.10:404. □

The model has proved particularly useful for evaluating revolutionary new hatchery management techniques developed by the Washington State Department of Fisheries. These techniques have proved that it is possible to rear salmon successfully and economically in a hatchery beyond the natural release time. The longer fish are held, the larger they become and the greater their chances for survival. As a result, more adult salmon are caught by the fisheries. In addition, by relieving the hatchery manager of complex calculations, the model makes practical the concept of "multiple releases"—releasing a single brood of salmon several times during each year rather than all at once—which increases the efficiency of the hatchery.

According to Johnson, the model has proved tremendously successful in its implementation. It has been adopted for use by the State, and current tests indicate a minimum of 15 to 25 percent improvement in the benefit/cost ratio of the hatcheries where it has been introduced. If, for example, a hatchery normally spent $1 for every $10 of fish that were eventually caught by a fishery, the benefit/cost ratio would be 10-1. If this ratio were improved by 20 percent, the fishery would catch $12 worth of fish for the same $1 investment by the hatchery. In a multimillion dollar industry, small improvements in the benefit/cost ratio are significant. Johnson says that, in some hatcheries, up to a 50 percent improvement has been projected.

The "Salmon" Indians

Even as Johnson and Bergman were working on the hatchery model, a legal battle was evolving that ultimately led to the fishery model project. The battle centered around the fishing rights of the various Indian tribes in the State, which form a part of the Pacific Northwest "Salmon" Indians. From earliest times, these tribes, which include the Quinault, Makah and Skokomish among others, were dependent on salmon for their subsistence and trade with other tribes. Salmon were also involved in their tribal customs and religion.

The fishing rights of Makah Indians such as these were protected by treaties signed in the 1850's. Photo courtesy Smithsonian Institution National Anthropological Archives.

In the 1850's these tribes signed treaties with the Federal Government. The treaties guaranteed the Indians "the right of taking fish at all usual and accustomed grounds and stations . . . in common with all citizens of the Territory." Over the years, as the State was settled and the commercial fishery industry grew, fewer salmon succeeded in returning upstream to the Indian's accustomed grounds. Last winter, the Quinault tribe, on its own behalf and on behalf of 13 other tribes, sued the State.

In February, a Federal district court judge ruled that the treaties must be upheld and that the "in common" phrase of the treaty meant 50 percent of the fish. The judge said that if, for some reason, State laws or regulations somehow affected the volume of fish available to the Indians, the regulations would have to be changed so that the Indians get their fair share.

Against this backdrop, the purpose of the fishery model is to analyze the

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impact that State regulatory policies designed to get more fish to the Indians would have on the commercial fisheries and on the long-term stability of the many salmon stocks which contribute to the fisheries. "One of the applications of the model is to serve as a quantitative tool for resolving conflicts which now exist between the established commercial and sport fishing industries and rapidly developing Indian fishing interests," says Johnson.

One of 26 hatcheries operated by the State of Washington to sustain and rehabilitate natural runs of Pacific salmon.

Fishery Model

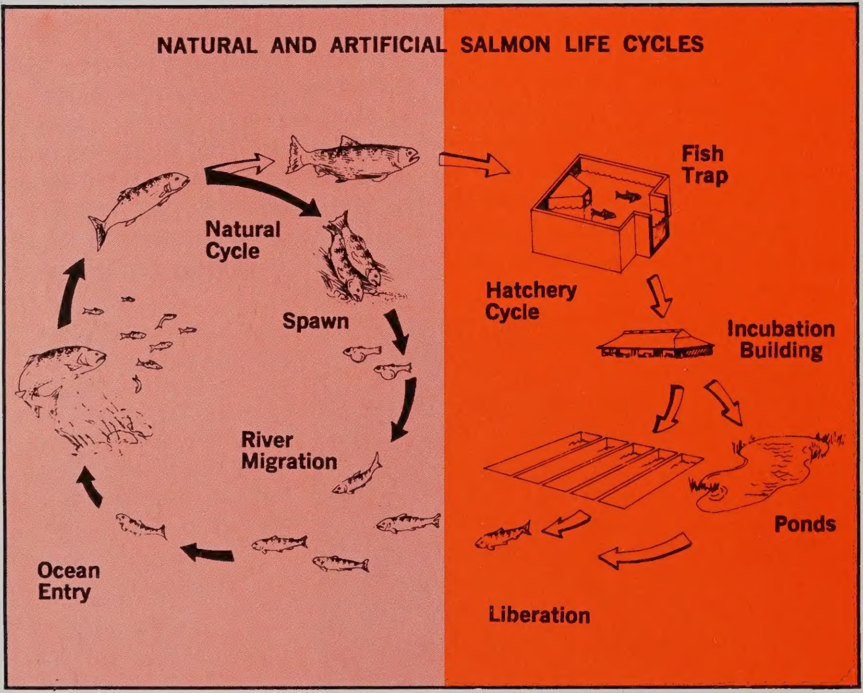
The fishery model promises to be even more complex than the hatchery model, he believes. The Pacific Coast salmon fisheries are a highly involved system in which each stock may be fished concurrently or sequentially by several types of fishing gear.

The fisheries are selective by species, age and size and the act of fishing can cause substantial induced mortality on sub-legal sized fish and on species with closed seasons. The sum of these factors is a complex set of interacting processes which must be controlled and regulated by fishery management agencies to obtain an economically productive and biologically sound fisheries system, Johnson notes.

The fishery model, as it is being developed, uses a set of mathematical relationships to represent the principal processes and interactions of the four major components of fishery management—salmon life cycle, structure of the fisheries, regulatory possibilities and economics of the fisheries. The model will use these relationships to evaluate the impact and performance of the fisheries under a specified set of regulatory parameters.

"The whole system is subject to many types of fluctuations," declares Johnson. "Moreover, the courts have not entirely resolved the issue since more suits are expected by the State. The NBS model is an attempt to provide technical information for economic and political decisions."

From the State's point of view, Bergman says, "The important factor in the success of this project is the overall cooperation we've had obtaining solutions to very complex problems by using many kinds of expertise, both here in the State and at NBS." □



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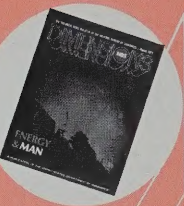

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